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PROPANE-BUTANE FRACTIONS OF PETROLEUM GASES AS FUEL IN INTERNAL COMBUSTION ENGINES

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Production of liquefied propane-butane gases is a new but well-developed field of the petroleum industry.

Due to their capability of liquefaction under low pressure, propane-butane gases are very convenient for long-range transportation.

Soviet plants, in particular those of the Ukraine, located, for example, at Kiev, Odessa, and Mariupol', manufacture railroad and automobile carriers, gas tanks of various sizes, pressure regulators, burners, and other items.

Following are the most essential characteristics of propane, n-butane, and isobutane, basic constituents of the mixture of liquefied hydrocarbon gases.

	Propane	n-Butane	Isobutane
Heating value (total), Cal/cu m.	22,400	29,000	29,000
Latent heat of evaporation (at boiling point), Cal/kg	102	94	91
Upper and lower limits of inflammation (% of gas in gas-air mixture)	2.4-9.6	1.8-8.5	1.8-8.5
Boiling point, °C	-44.6	+ 0.5	-10.2
Amount of air, required for complete combustion (theoretical), cu m/cu m	24.0	31.1	31.1
Volume of vapors at 1 atm and 15°C from 1 liter of liquid, cu m	0.272	0.236	0.228

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With regard to the use of liquefied gases as a fuel for internal combustion engines, it is necessary especially to appraise their antiknock properties.

Mean octane ratings for liquefied gases are as follows:

Propane (C_3H_3)	125
n-Butane (C_4H_{10})	91
Isobutane (C_4H_{10})	99

High antiknock qualities of the components of liquefied gases permit increased compression ratios in engines operated on these gases.

Permissible compression ratios for internal combustion engines operated on propane-butane fractions are in the range of 6.5-10.0, depending on the mixture compostition. The lower limit is for butane, and the upper one for propane.

For comparison, here are the values accepted for compression ratios in ordinary gas, gasoline, and kerosene engines:

Gas engines	5.5-7.3
Gasoline engines	
air cooled	4.5-5.3
water cooled	4.8-5.8
Kerosene engines	3.5-4.5

Elevated compression ratios in engines operating on the propane-butane mixture or on pure propane permit an increase in engine power of 25-30%. A. Romen and D. Krappe give the following experimental data obtained from running a six-cylinder 4" x 5" engine on gasoline, propane, and butane:

Fuel	Compression R	Max Power (h p)	Av Fuel Consumption (Cal/h p-hr)
Propane	9.95	99.0	2,830
Butane	6.75	86.8	3,140
Butane	4.38	66.0	3,850
Gasoline	4.38	63.4	3,835

Liquefied gases in which such light hydrocarbons as propane and butane are predominant fractions, differ considerably from ordinary fuels. The gas, as a rule, is received in its vapor phase (from the space over its liquid portion), and this factor facilitates the starting of the engine and eliminates preheating. It should also be noted that propane-butane fractions have another beneficial property in comparison with low-volatile fuels: they do not dilute the lubricant, thus eliminating the danger of washing lubricating oil from the cylinder walls, a factor which improves operational conditions in an engine and increases the period between overhauls.

Increase in the rated horsepower of an engine, in the case of its conversion to liquefied gas, naturally involves certain design modifications, connected basically, with an increase in the compression ratio.

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Conversion of gasoline-kerosene engines to operation on ordinary-power gas leads to a noticeable decrease in their effective power. The main ca se for such a decrease is the lower heating capacity of the gas-air mixture, using standard synthetic-power gas (500-550 cal/cu m) in comparison with the gasoline-air mixture (800-850 cal/cu m).

Conversion of such engines tc use mixtures of liquefied gases, especially those with predominance of the propane fraction (ignition point in air 510-580°C), not only permit maintaining the heating value of the mixture, but also makes it possible ɔ surpass considerably the rated power of an engine by increasing the compression ratio.

The value of the compression ratio is clearly expressed in the well-known forumula: $\eta_t = 1 - \frac{1}{\varepsilon^{k-1}}$. Theoretical efficiency of the cycle is completely determined by the degree of adiabatic compression or expansion, rising with their increase. By raising ε, we decrease the outflow of heat or increase the inflow of heat which is given to the working medium during the combustion process.

Under proper conditions, a sharp increase in thermal efficiency is possible for engines operating according to the Otto cycle when they are converted for feeding with a propane fraction.

It should be noticed that incomplete combustion of ordinary petroleum fuels in the cylinders of diesel engines causes scale formation, which sometimes is very damaging to the engine. The tendency of fuels toward forming scale in cylinders may be explained not only by methods for atomization of fuel and its mixing with air, but, to a great extent, by the composition of the fuel itself and by the content of heavy, high-molecular hydrocarbons. It should be remembered that the higher the speed of an engine, the lighter the fuel required.

The presence of sulfurous compounds in fuels is one of the factors which complicate the combustion process in engines, since such compounds cause corrosion of the exhaust system and other difficulties.

Propane-butane gases, as a fuel for internal combustion engines, are characterized by their low-molecular nature as well as by the complete absence of sulfurous admixtures. In this respect the propane-butane gases may be considered an ideal fuel.

The author investigated the performance of a nonstationary, four-cycle gasoline engine, converted to liquefied gas, with an electric generator. The engine was mounted on a chassis with a built-in tank for the propane-butane mixture. The capacity of the tank was 16 kg.

The power of the engine was 2.4 kwt. The engine developed rated power, and consumption of liquefied gas varied, depending on load, in the range from 3,700 to 5,000 Cal/kwh.

No alterations were made in the engine. A single-stage gas reducer manufactured by the "Gazoapparat" Plant in Kiev was installed between the tank and mixer. During the testing period the engine worked steadily under various load conditions.

Kerosene-gasoline engines may develop their rated power on liquefied gas without any modification. Installations of this type may obtain wide application for power supply and lighting purposes.

Liquefied gases having high thermal concentration per unit volume may also serve as an excellent reserve fuel for gasoline and oil engines.

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Regarding the wide possibilities for using liquefied gases with respect to a considerable increase in the resources of these gases and the mass production of special transportation equipment, it is well to consider not only the adaptation of existing engines to operate on propane-butane fractions, but also the development and manufacture of special types of engines, the design of which would take into consideration the properties and effectiveness of this new type of fuel.

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